SOSIGENES LUNAR IRREGULAR MARE PATCH (IMP): GEOLOGY AND A VOLCANIC ERUPTION FORMATION MODEL CONSISTENT WITH THE ANCIENT AGE OF ADJACENT MARIA. L. Qiao[1, 2], J. W. Head[2], L. Xiao[1], L. Wilson[3] and J. Dufek[4], [1]Planet. Sci. Inst., China Univ. Geosci., Wuhan 430074, China, [2]Dep. Earth, Env. & Planet. Sci., Brown Univ., Providence, RI, 02906, USA, [3]Lancaster Env. Centre, Lancaster Univ., Lancaster LA1 4YQ, UK, [4]Sch. Earth & Atmos. Sci., GA Tech, Atlanta, GA, 30332, USA. Contact: LeQiao.GEO@Gmail.com, James_Head@Brown.edu.

Introduction: Irregular Mare Patches (IMPs) are a group of endogenic mare features on the Moon, notable for their "blistered" appearance (meniscus-like bulbous shaped mounds with surrounding rough and optically immature materials). Since the discovery of the most notable IMP feature Ina on Apollo photographs [1], the formation mechanism of IMPs has been long debated, including individual lava extrusions [2], very recent venting of juvenile volatiles [3], lava flow inflation process [4], pyroclastic deposition [5], a mixed formation process [6], etc. Specifically, a recent analysis suggested that they represent volcanic eruptions within the last 100 Myr of lunar history [7], which, if true, requires a major rethinking of the current and past interior thermal regimes of the Moon.

In order to re-assess the origin of the unusual lunar IMPs, we focus on Sosigenes (Fig. 1), one of the major IMP occurrences, first found on the western margin of Mare Tranquillitatis (8.34°N, 19.07°E) in Lunar Reconnaissance Orbiter Camera (LROC) images [8]. Sosigenes is also the largest, and most areally extensive among the dozens of IMPs identified on the central nearside of the Moon [7]. This contribution is a continuation of our preliminary characterization of the morphology, topography, sub-resolution roughness of Sosigenes [9]; here we reported some updated analyses, including geologic setting, impact crater populations and a specific formation mechanism. An accompanying analysis of another major IMP, Ina, is also presented (abstract #1126, [10]).

Geologic Setting: The Sosigenes IMP occurs on the floor of an ~7×3 km elongate pit crater. This pit crater is a portion of a chain of co-aligned pit craters, crater chains and linear ridges, which are arrayed in an orientation normal to the strike of Rima Sosigenes and radial to the center of Mare Tranquillitatis (Fig. 2). We interpret these linear features to represent different surface manifestation of magmatic dike propagation processes towards the surface: the Sosigenes IMP-hosting pit crater is related to the collapse of the gas cavity at the top of the dike; the easternmost linear ridge is related to extrusion downslope in the Tranquillitatis basin, formed in the waning stages of dike emplacement and dike closure, as the relatively cooled residual magma in the dike was extruded to the surface (Fig. 16 of [11]). As is common in some lunar collapse pits (e.g., Hyginus [11]), the floor of the larger pit may have been resurfaced in the context of the post-collapse closing of the dike and extrusion of

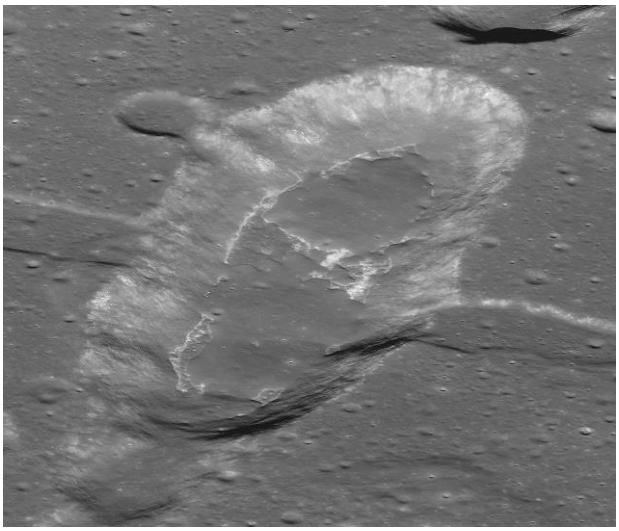

Fig. 1. Perspective view of Sosigenes IMP, the depression floor is ~5.1×1.4 km. LROC NAC M1108117962, incidence angle =~71°, pixel size =~2.5 m.

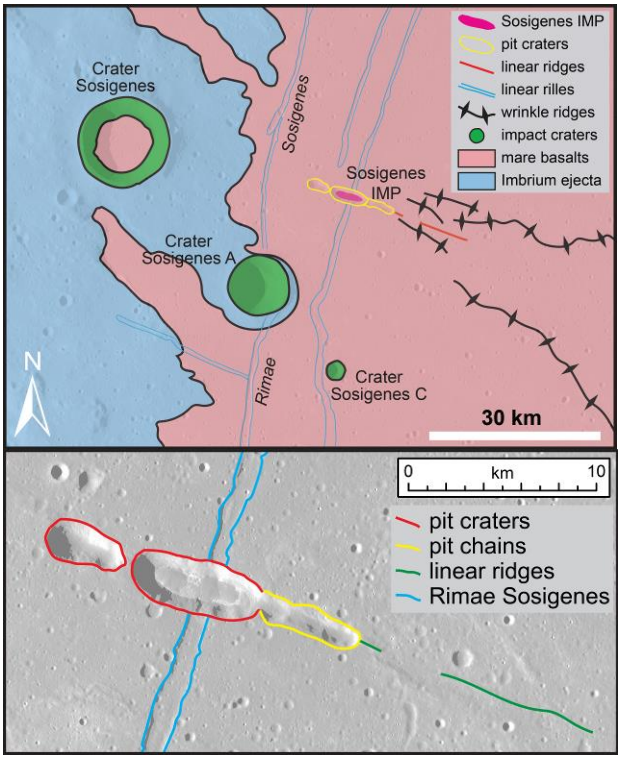

Fig. 2. Regional (upper) and localized (lower) geologic setting of Sosigenes IMP, Kaguya TC evening mosaics as background.

basaltic magma onto the pit floor in the same manner that produced the extrusive ridge [12]. These dike propagating processes are predicted to have operated during the mare basalt emplacement era >3 Byr ago [13].

Impact Crater Populations: One of the most unusual characteristics of lunar IMPs is their apparently low number of superposed impact craters, yielding a crater retention age of <100 Ma (specifically, 18.1 Ma for Sosigenes [7]). To explore the potential causes of the extremely low crater density, we counted all impact craters ⩾10 m in diameter on the Sosigenes mounds and a 2×2 km mare surface surrounding Sosigenes IMP (Fig. 3) using LROC NAC images with a range of illumination geometries. Compared with [7], we identify significantly more impact craters on the Sosigenes mounds (662 vs. 286), which yield an older absolute model age (48 Ma vs. 18.1 Ma). The mare crater counting gives an absolute model age of 3.46 Ga, broadly consistent with [13].

Formation Mechanism of Lunar IMPs: Using new volcanological interpretations for the ascent and eruption of magma in dikes, and dike degassing and extrusion behavior in the final stages of dike closure [11, 12], we interpret the units comprising the Sosigenes pit crater floor to be related to the late-stage behavior of an ancient dike emplacement event coincident with the general mare emplacement phase. Following the initial dike emplacement and collapse of the pit crater, the floor of the pit crater was flooded by the latest-stage magma. The low rise rate of the magma in the terminal stages of the dike emplacement event favored flooding of the pit crater floor to form a lava lake, and CO gas bubble coalescence initiated a strombolian phase disrupting the cooling lava lake surface. This phase produced a very rough and highly porous (with both vesicularity and macro-porosity) lava lake surface as the lake surface cooled. In the terminal stage of the eruption, dike closure with no addition of magma from depth caused the last magma reaching shallow levels to produce viscous magmatic foam due to H_2O gas exsolution. This magmatic foam was extruded through cracks in the lava lake crust to produce the bulbous mounds. We interpret all of this activity to have taken place in the terminal stages of the dike emplacement event >3 Byr ago. We attribute the unusual physical properties of the mounds and floor units (anomalously young crater retention ages, unusual morphology, relative immaturity, and blockiness) to be due to the highly porous substrate produced during the waning stages of a dike emplacement event in a pit crater. The unique physical properties of the mounds (magmatic foams) and hummocky units (small vesicles and large void space) altered the nature of subsequent impact cratering, regolith development and landscape evolution, inhibiting the typical formation and evolution of superposed impact craters, and maintaining the morphological crispness and optical immaturity. Accounting for the effects of the reduced diameter of craters (~30% [14, 15]) formed in magmatic foams (assuming a porosity of 75%) results in a shift of the crater size-frequency distribution age from <100 Ma to >3 Ga (Fig. 3), contemporaneous with the surrounding ancient mare basalts. We conclude that extremely young mare basalt eruptions, and resulting alteration of lunar thermal evolution models to account for the apparent young ages of the IMPs, are not required. We suggest that other IMP occurrences, both those associated with pit craters atop dikes and those linked to fissure eruptions in the lunar maria, may have had similar ancient origins.

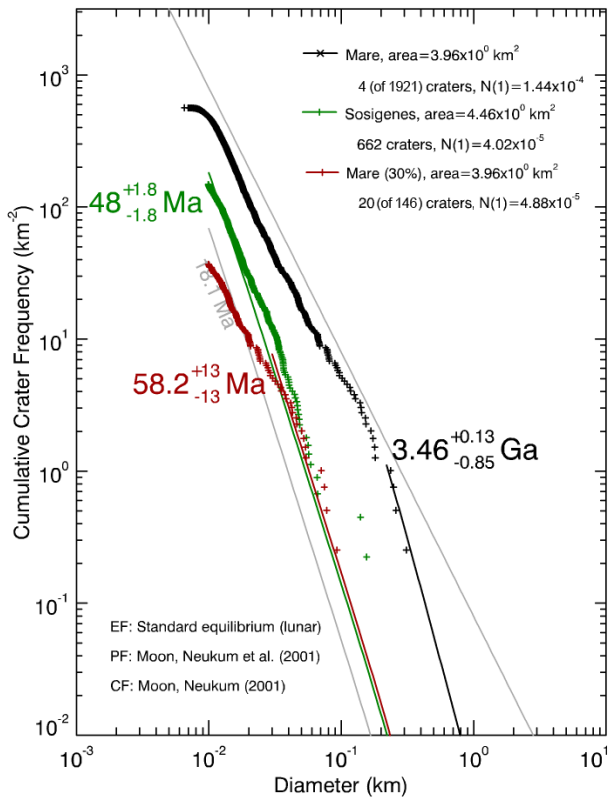

Fig. 3. Impact crater populations analysis of the Sosigenes mounds (green crosses), surrounding mare (black crosses), and the effect of reduced crater diameter (~30%), caused by the high porosity of the magmatic foam, on the crater retention age (red crosses).

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